# Cosmic Microwave Background Analysis Tools (COMBAT) II Annual Report For FY05

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The Cosmic Microwave Background Analysis Tools (COMBAT) project develops massively parallel implementations of data analysis algorithms and provides them as a toolkit for the CMB community. To maintain the relevance of the development path, and to demonstrate the capabilities of the tools, the COMBAT team also applies the tools to real and simulated leading-edge CMB datasets.

In this, the final year of COMBAT II, we have been working to complete the coordination, integration, and documentation of our codes. The major component of the toolkit is the Microwave Anisotropy Dataset Computational Analysis Package (MADCAP). Now in its 4th generation, MADCAP now encompasses:

- M3 - a library for managing CMB datasets on disk, including an XML data definition layer and suite of abstracted I/O tools the allow the analysis codes to be written independent of the data distribution and format.
- MADnes - derives the piecewise stationary noise correlation properties of a CMB time-ordered dataset and fills timestream gaps with an appropriately constrained noise realization in order to provide continuous data for subsequent fourier analysis.
- MADmap - solves the maximum likelihood solution for the microwave sky temperature and polarization maps given the estimated noise properties by preconditioned conjugate gradient.
- MADpre - generates the trivially invertable white-noise approximation to the full pixel-pixel noise correlation matrix for use as a conjugate gradient preconditioner by MADmap.
- MADmask - generates a mask to remove from the timstream data observations of pixels which will be degenerate in the map-making phase.
- MADping - constructs the full pixel-pixel noise correlation matrix by explicit dense symmetric matrix inversion.
- MADspec - calculates the maximum likelihood CMB temperature and polarization auto- and cross-spectra from the maximum likelihood maps and the associated pixel-pixel noise correlation matrix.
- MADbench - a benchmarking version of MADspec that is used to measaure the performance of supercomputers under the stresses of real scientific codes.

This work is nearing completion, and will be presented in a publication currently in preparation.

We have also continued to apply our tools to the largest and most challenging datasets as tests of their capabilities. In particular this year we performed the first ever analysis of a full year of simulated data from the key CMB frequency of the joint ESA/NASA Planck satellite mission. This work demonstrated

1. the capability of the MADCAP codes to ingest this volume of data and process it efficiently over very large numbers of processors.
2. the extraordinary quality of the CMB maps that we can expect from the Planck mission, both in resolution and signal-to-noise.
3. the resolution of the CMB power spectra that we can expect to extract from these maps (incidentally addressing questions that had been raised about Planck's sensitivity on large angular scales).

These results were presented at the 2005 American Astronomical Society meeting, and can be seen in detail at http://crd.lbl.gov/ borrill/downloads/planck/poster.html

The MADbench code has been used both in the procurement of the new "Jacquard" supercomputer at the DoE's National Energy Research Scientific Computing (NERSC) center, but also for comparative investigations of the performance of NERSC's "Seaborg", NASA's "Project Columbia", the Japanese "Earth Simulator", and the Oak Ridge Laboratory's "Phoenix". This work was presented at the 2005 International Conference on Parallel Processing, where it was shortlisted for the best paper award.

Although this was to be the final year of the award, we will be requesting a 6-month no-cost extension due to the long-term sickness of the postdoctoral position holder over the last year. This extension will enable us to complete the final integration, distribution and publication of the MADCAP suite.